US009300720B1

(12) **United States Patent**
Qiu et al.

(10) **Patent No.: US 9,300,720 B1**
(45) **Date of Patent: Mar. 29, 2016**

(54) **SYSTEMS AND METHODS FOR PROVIDING USER INPUTS TO REMOTE MOBILE OPERATING SYSTEMS**

(71) Applicant: **Trend Micro Incorporated**, Tokyo (JP)

(72) Inventors: **Yinfeng Qiu**, Nanjing (CN); **Yaozhou Xu**, Nanjing (CN); **Gen Chen**, Nanjing (CN)

(73) Assignee: **Trend Micro Incorporated**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 289 days.

(21) Appl. No.: **13/902,013**

(22) Filed: **May 24, 2013**

Related U.S. Application Data

(60) Provisional application No. 61/825,839, filed on May 21, 2013.

(51) **Int. Cl.**

H04L 15/16	(2006.01)
H04L 29/08	(2006.01)
H04L 12/66	(2006.01)
G06F 9/44	(2006.01)
G06F 9/455	(2006.01)
G06F 3/0488	(2013.01)

(52) **U.S. Cl.**
CPC ***H04L 67/04*** (2013.01); ***G06F 3/04883*** (2013.01); ***G06F 9/4445*** (2013.01); ***G06F 9/45504*** (2013.01); ***H04L 12/66*** (2013.01); ***H04L 67/1095*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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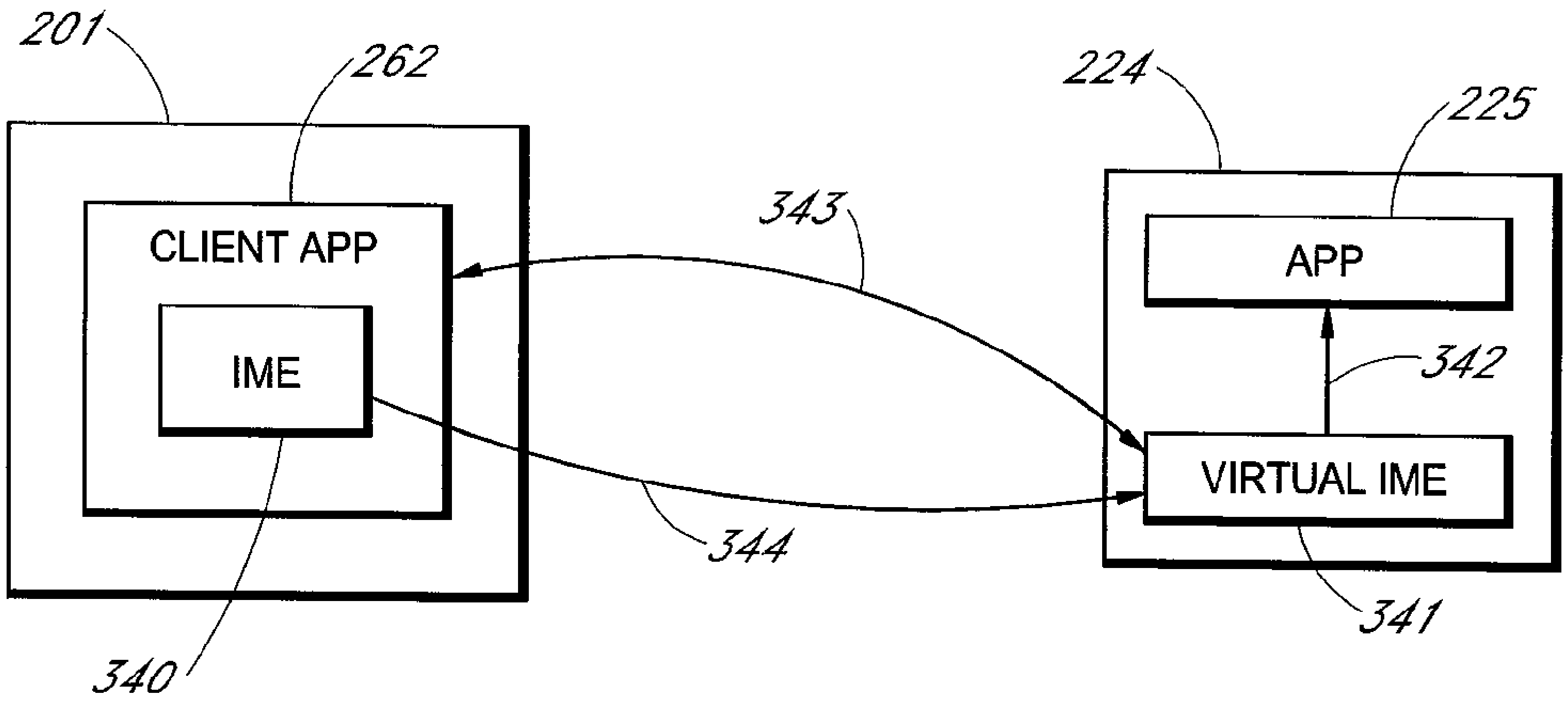
Primary Examiner — Ranodhi Serrao
Assistant Examiner — James Fiorillo
(74) *Attorney, Agent, or Firm* — Okamoto & Benedicto LLP

(57) **ABSTRACT**

A virtual mobile infrastructure includes a mobile client device running a local mobile operating system and a server computer running a remote mobile operating system. The mobile client device displays a screen image of the remote mobile operating system. User text inputs for a remote application running on the remote mobile operating system are received by way of a touchscreen keyboard of a local input method editor (IME) of the local mobile operating system. The user text inputs are transmitted from the mobile client device to the server computer, where the text inputs are provided to the remote application by a virtual IME of the remote mobile operating system.

11 Claims, 12 Drawing Sheets



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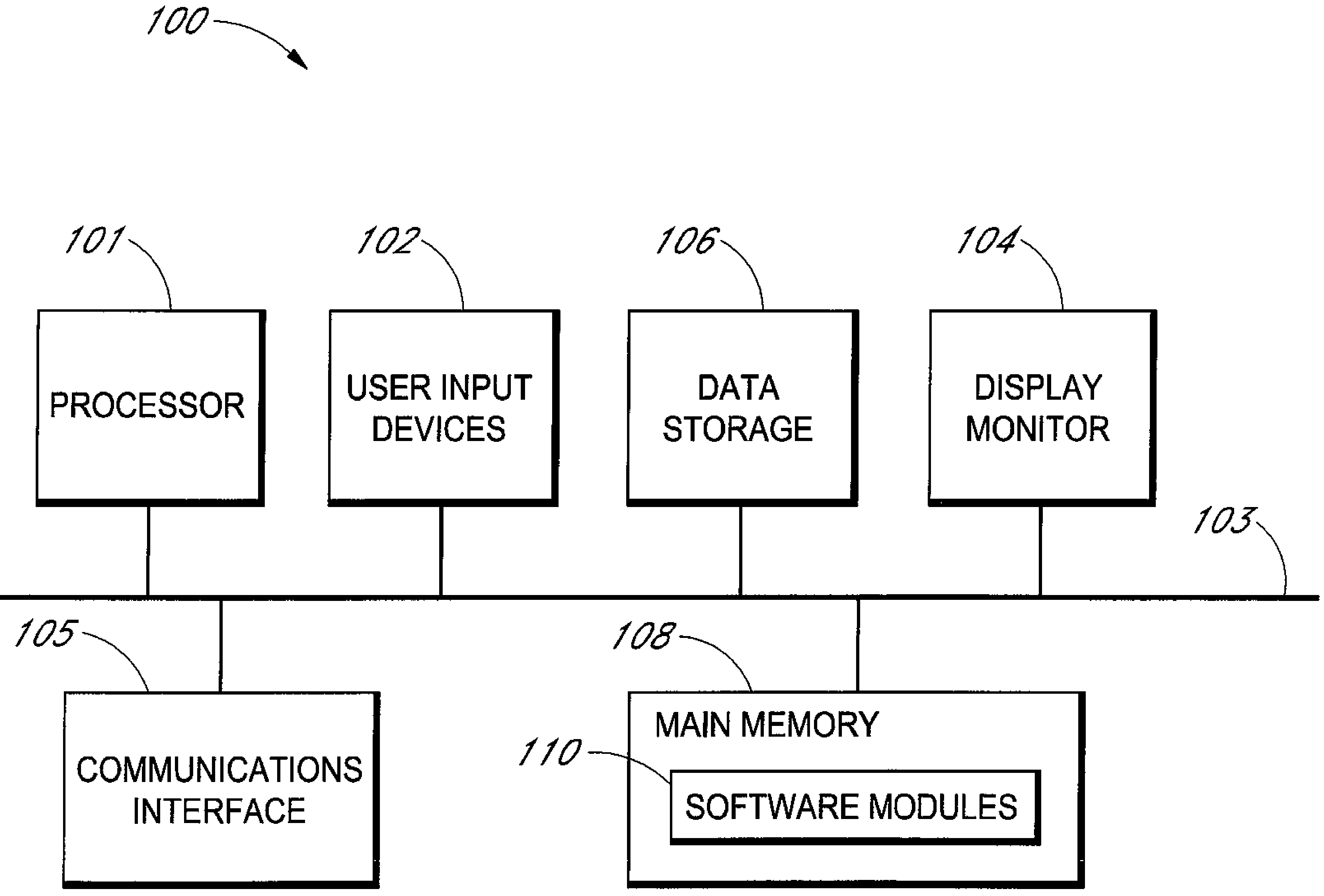
100
101
PROCESSOR
102
USER INPUT DEVICES
106
DATA STORAGE
104
DISPLAY MONITOR
103
105
COMMUNICATIONS INTERFACE
108
MAIN MEMORY
110
SOFTWARE MODULES

FIG. 1

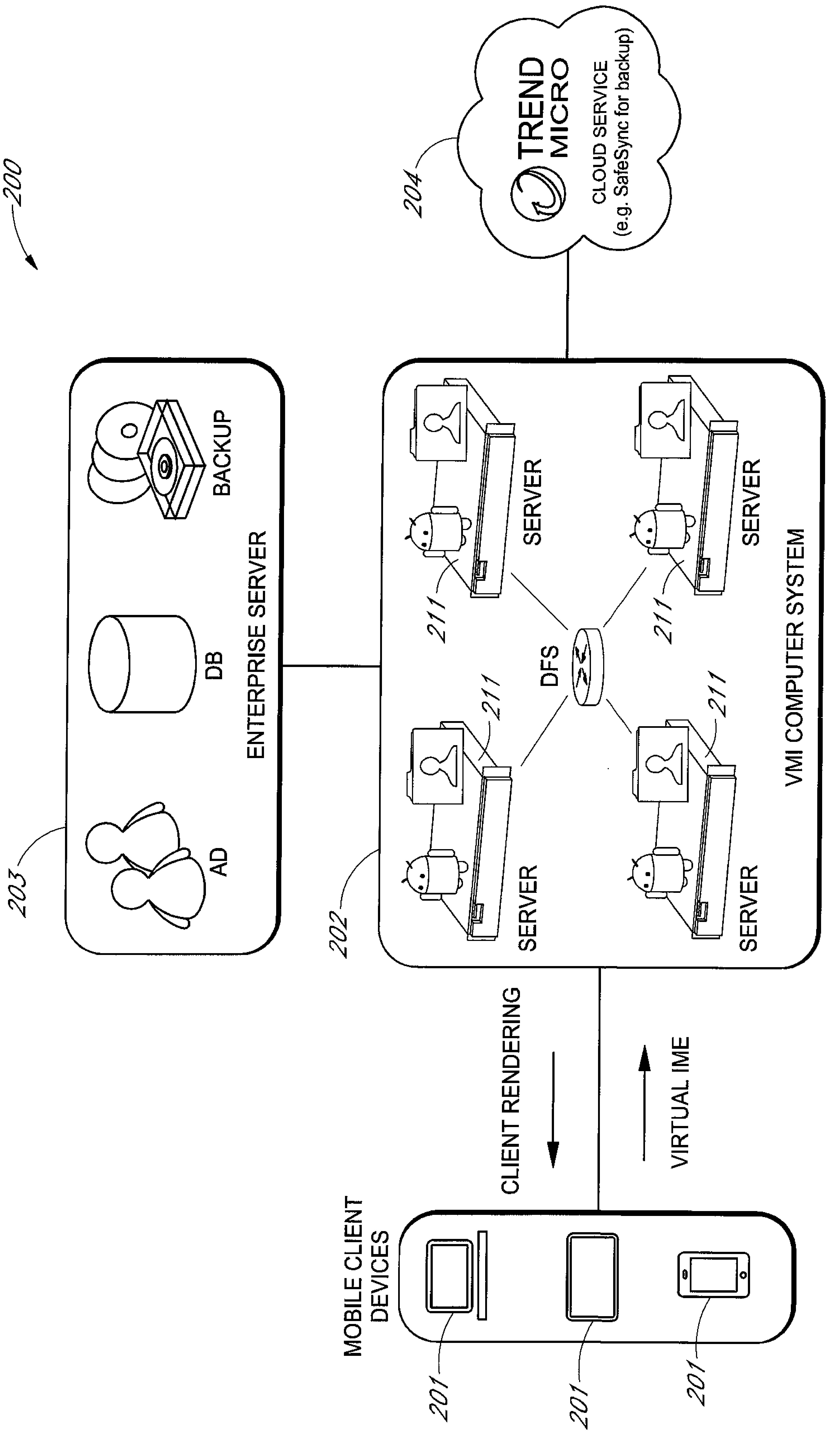
200
203
AD
DB
BACKUP
ENTERPRISE SERVER
202
SERVER
SERVER
SERVER
SERVER
211
211
211
211
DFS
VMI COMPUTER SYSTEM
204
TREND MICRO
CLOUD SERVICE
(e.g. SafeSync for backup)
CLIENT RENDERING
VIRTUAL IME
MOBILE CLIENT DEVICES
201
201
201

FIG. 2

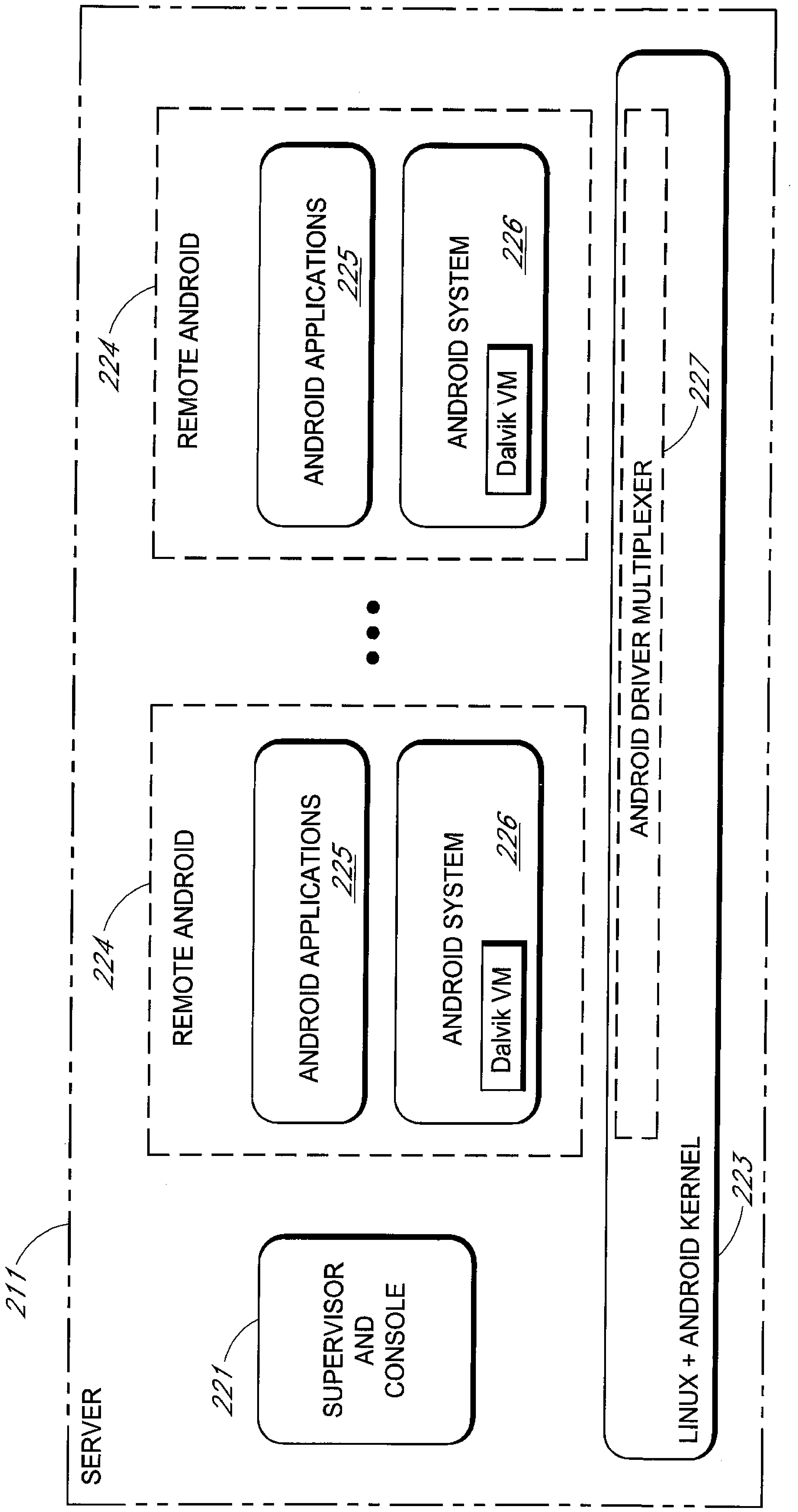
211
SERVER
221
SUPERVISOR AND CONSOLE
224
REMOTE ANDROID
ANDROID APPLICATIONS 225
ANDROID SYSTEM 226
Dalvik VM
224
REMOTE ANDROID
ANDROID APPLICATIONS 225
ANDROID SYSTEM 226
Dalvik VM
227
ANDROID DRIVER MULTIPLEXER
223
LINUX + ANDROID KERNEL

FIG. 3

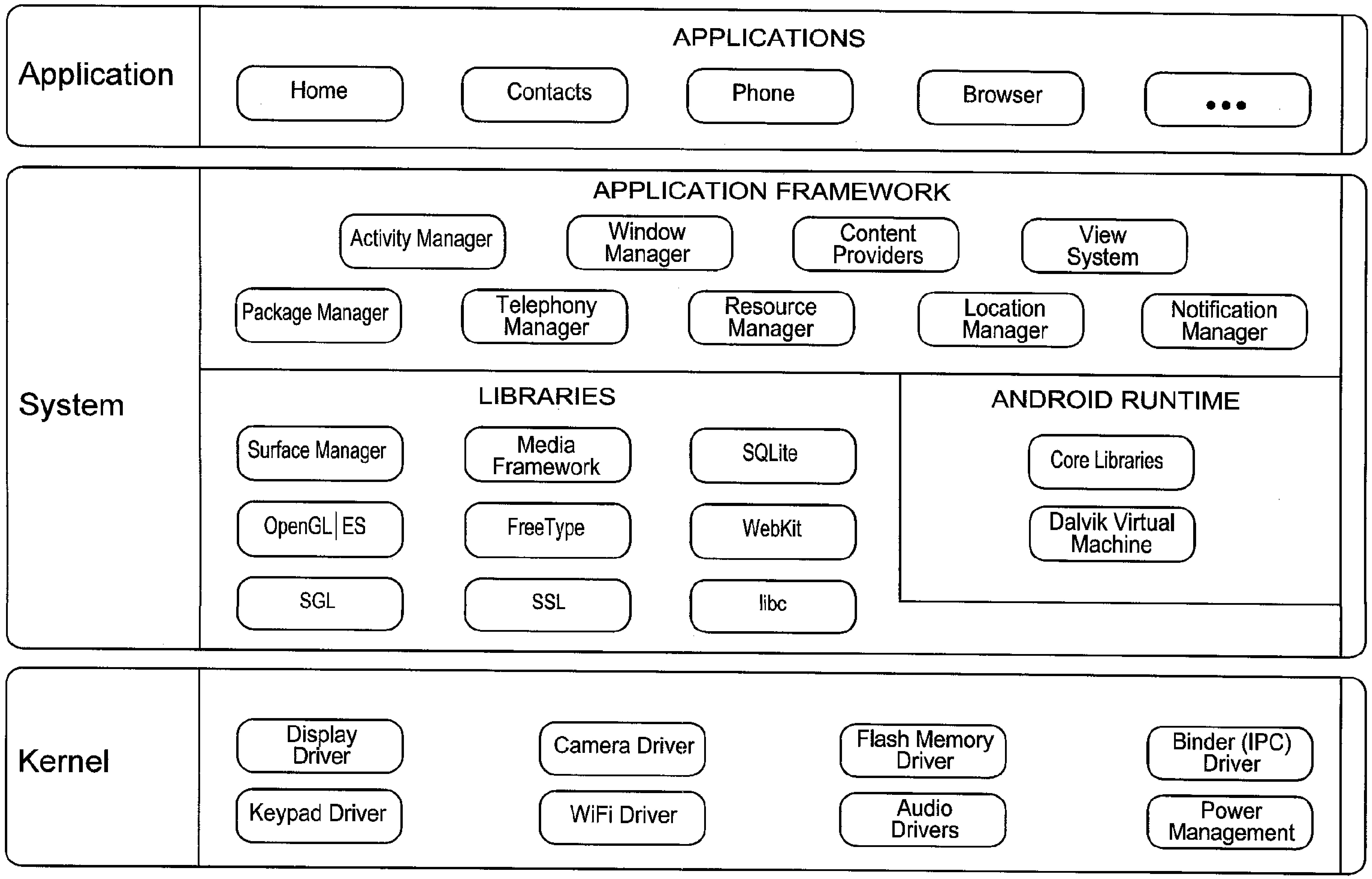

FIG. 4
(PRIOR ART)

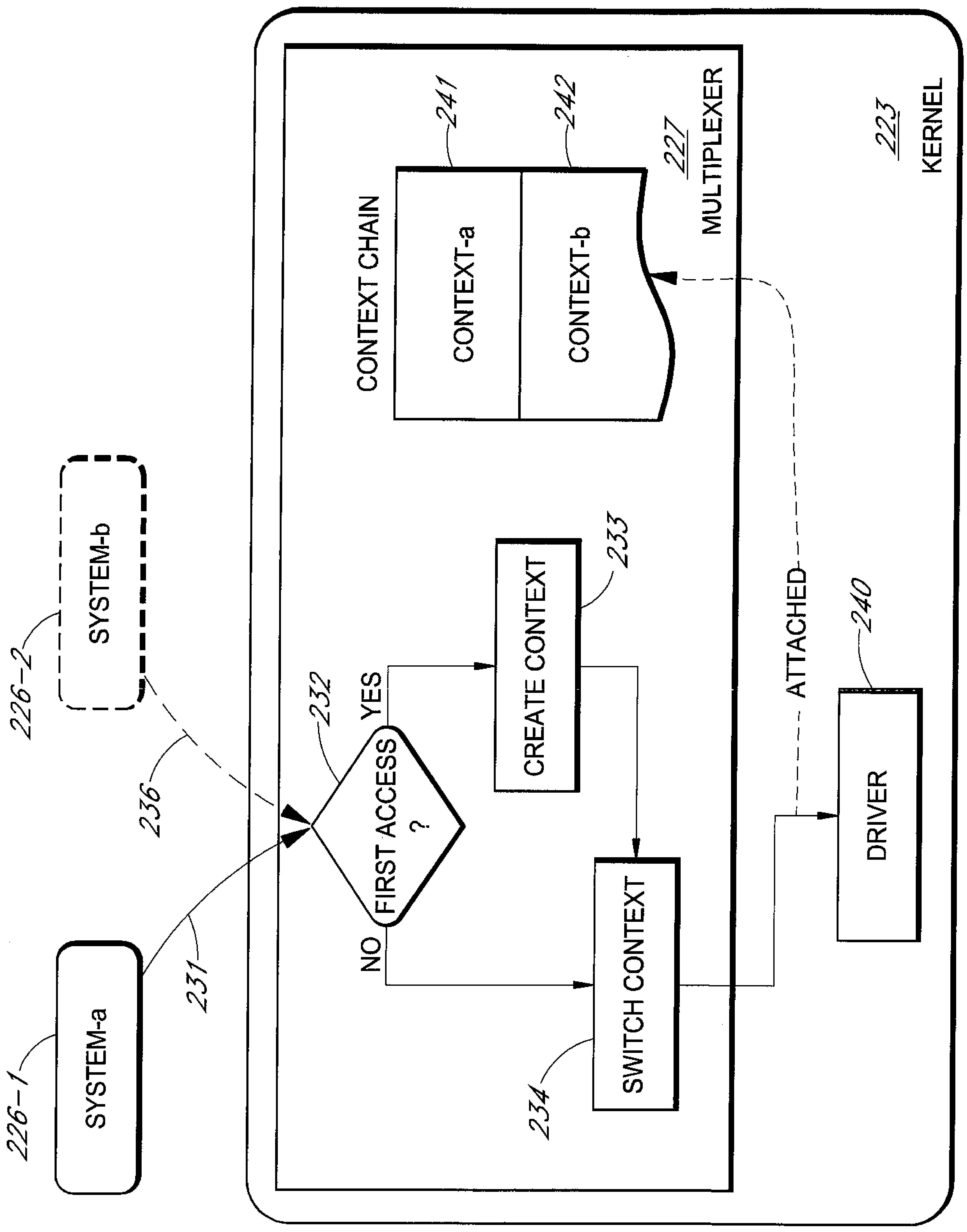
226-2
SYSTEM-b
236
226-1
SYSTEM-a
231
232
FIRST ACCESS ?
YES
NO
CREATE CONTEXT
233
SWITCH CONTEXT
234
CONTEXT CHAIN
CONTEXT-a
241
CONTEXT-b
242
227 MULTIPLEXER
ATTACHED
240
DRIVER
223 KERNEL

FIG. 5

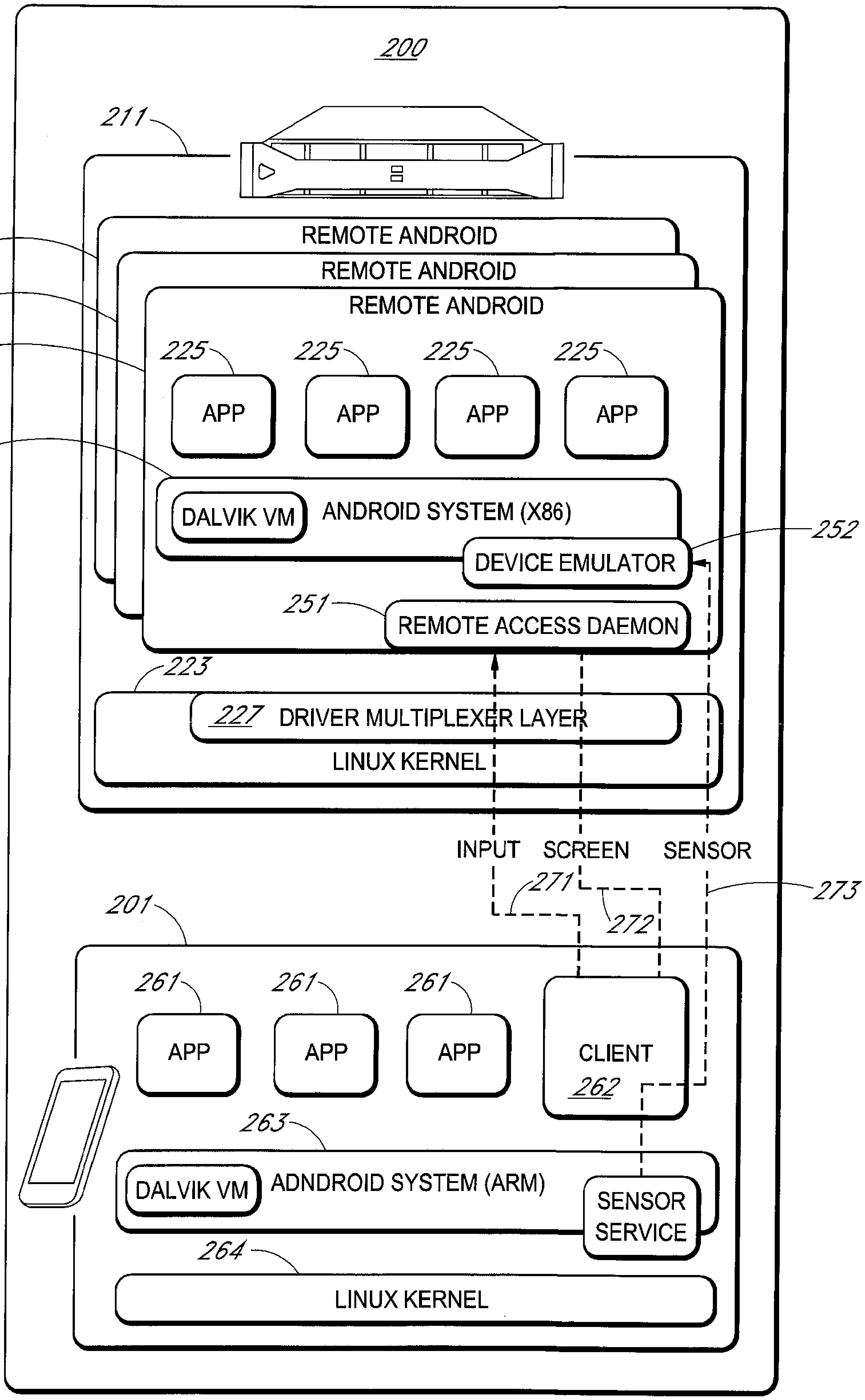
200
211
224
224
224
REMOTE ANDROID
REMOTE ANDROID
REMOTE ANDROID
225
225
225
225
APP
APP
APP
APP
226
DALVIK VM
ANDROID SYSTEM (X86)
252
DEVICE EMULATOR
251
REMOTE ACCESS DAEMON
223
227
DRIVER MULTIPLEXER LAYER
LINUX KERNEL
INPUT
SCREEN
SENSOR
271
272
273
201
261
261
261
APP
APP
APP
CLIENT
262
263
DALVIK VM
ADNDROID SYSTEM (ARM)
SENSOR SERVICE
264
LINUX KERNEL

FIG. 6

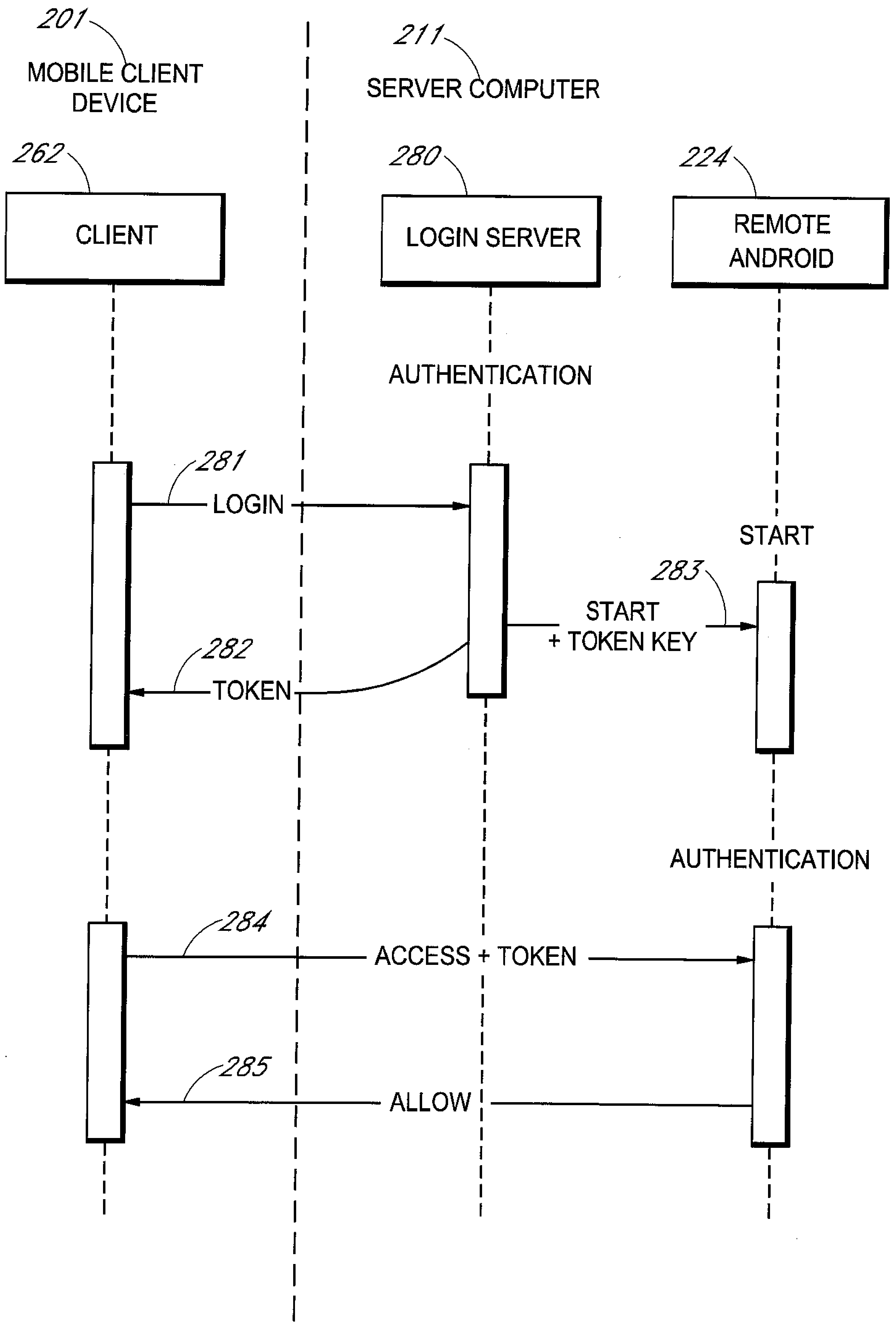
201
MOBILE CLIENT DEVICE
211
SERVER COMPUTER
262
CLIENT
280
LOGIN SERVER
224
REMOTE ANDROID
AUTHENTICATION
281
LOGIN
START
283
START + TOKEN KEY
282
TOKEN
AUTHENTICATION
284
ACCESS + TOKEN
285
ALLOW

FIG. 7

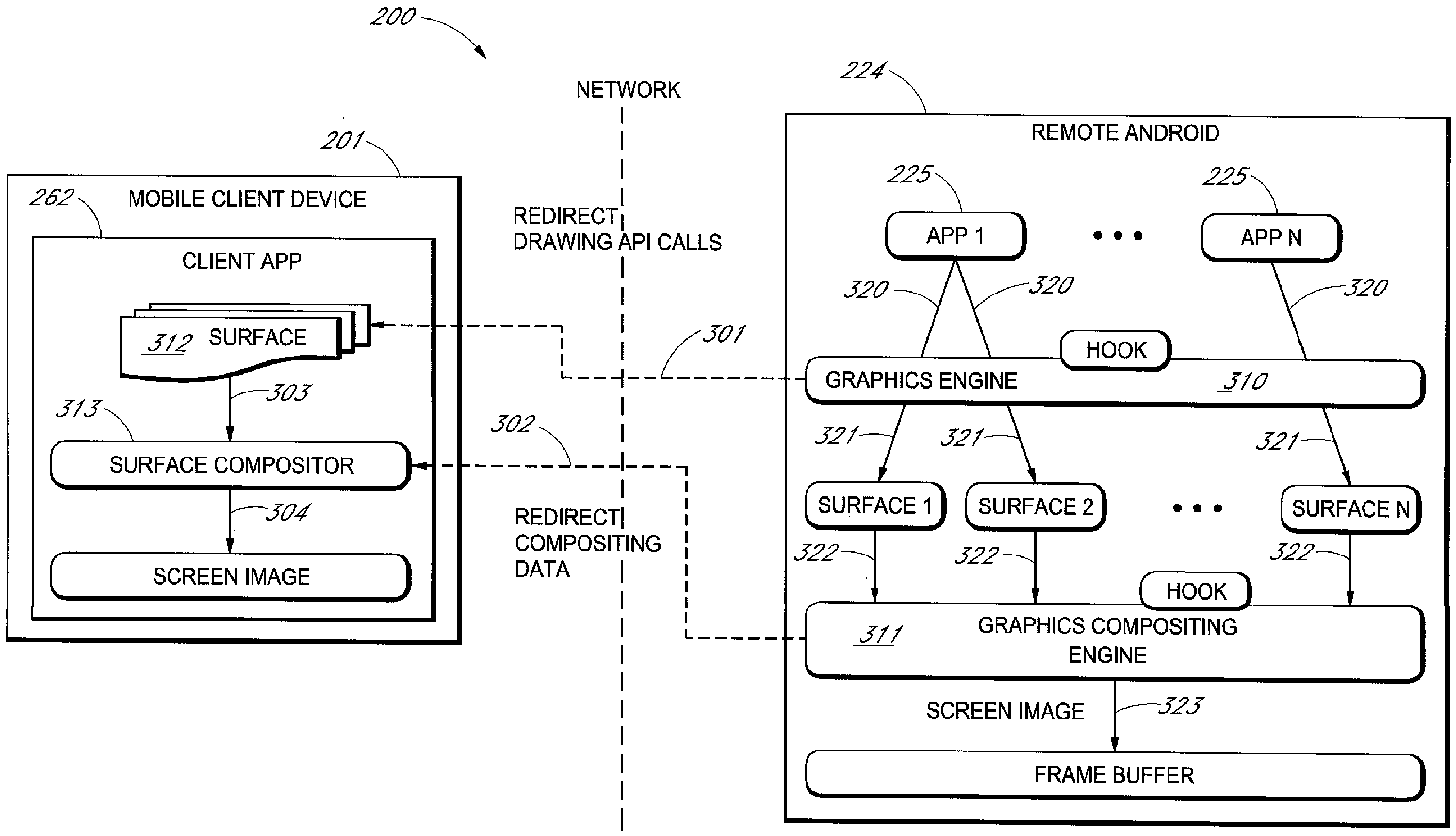
200
NETWORK
201
262
MOBILE CLIENT DEVICE
CLIENT APP
312
SURFACE
303
313
SURFACE COMPOSITOR
304
SCREEN IMAGE
REDIRECT DRAWING API CALLS
301
302
REDIRECT COMPOSITING DATA
224
REMOTE ANDROID
225
APP 1
225
APP N
320
320
320
HOOK
GRAPHICS ENGINE
310
321
321
321
SURFACE 1
SURFACE 2
SURFACE N
322
322
322
HOOK
311
GRAPHICS COMPOSITING ENGINE
SCREEN IMAGE
323
FRAME BUFFER

FIG. 8

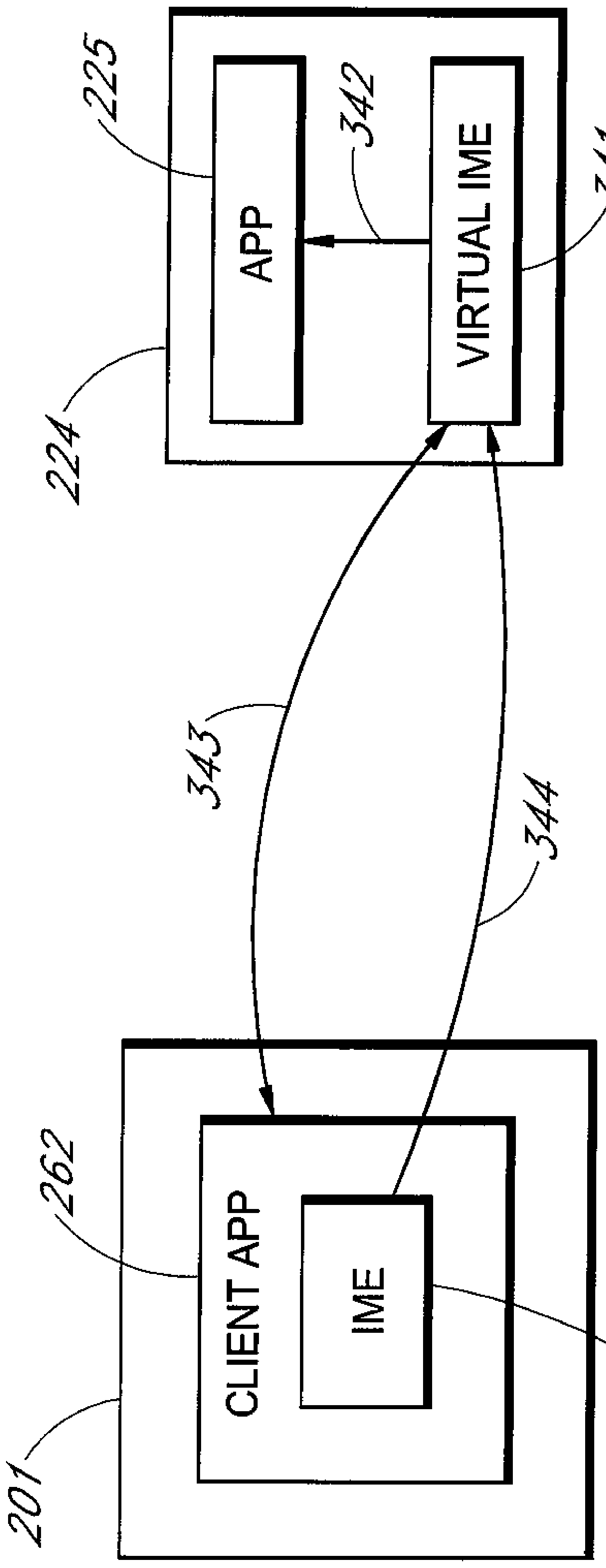
225
342
APP
VIRTUAL IME
341
224
343
344
262
CLIENT APP
IME
201
340

FIG. 9

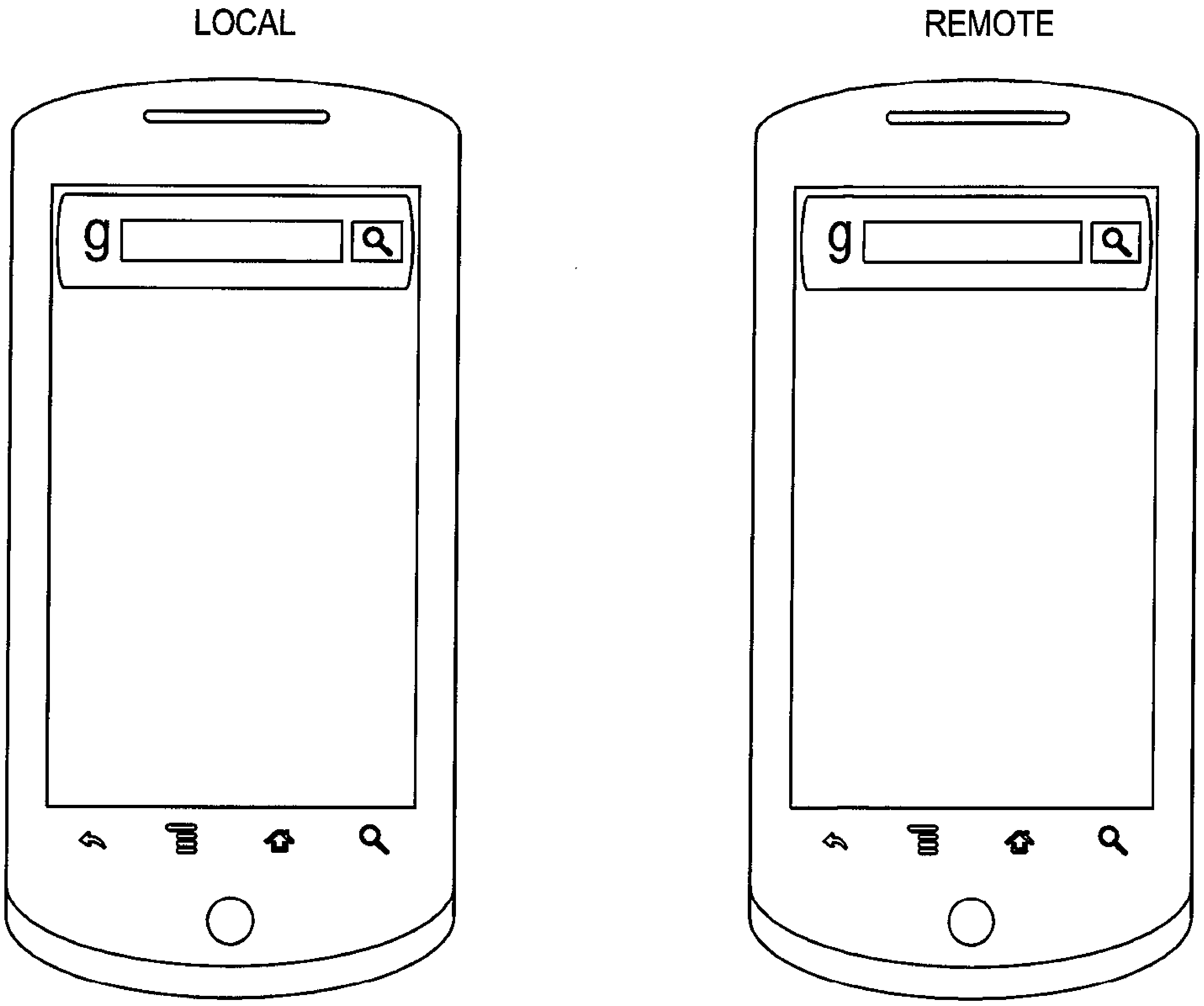

FIG. 10A

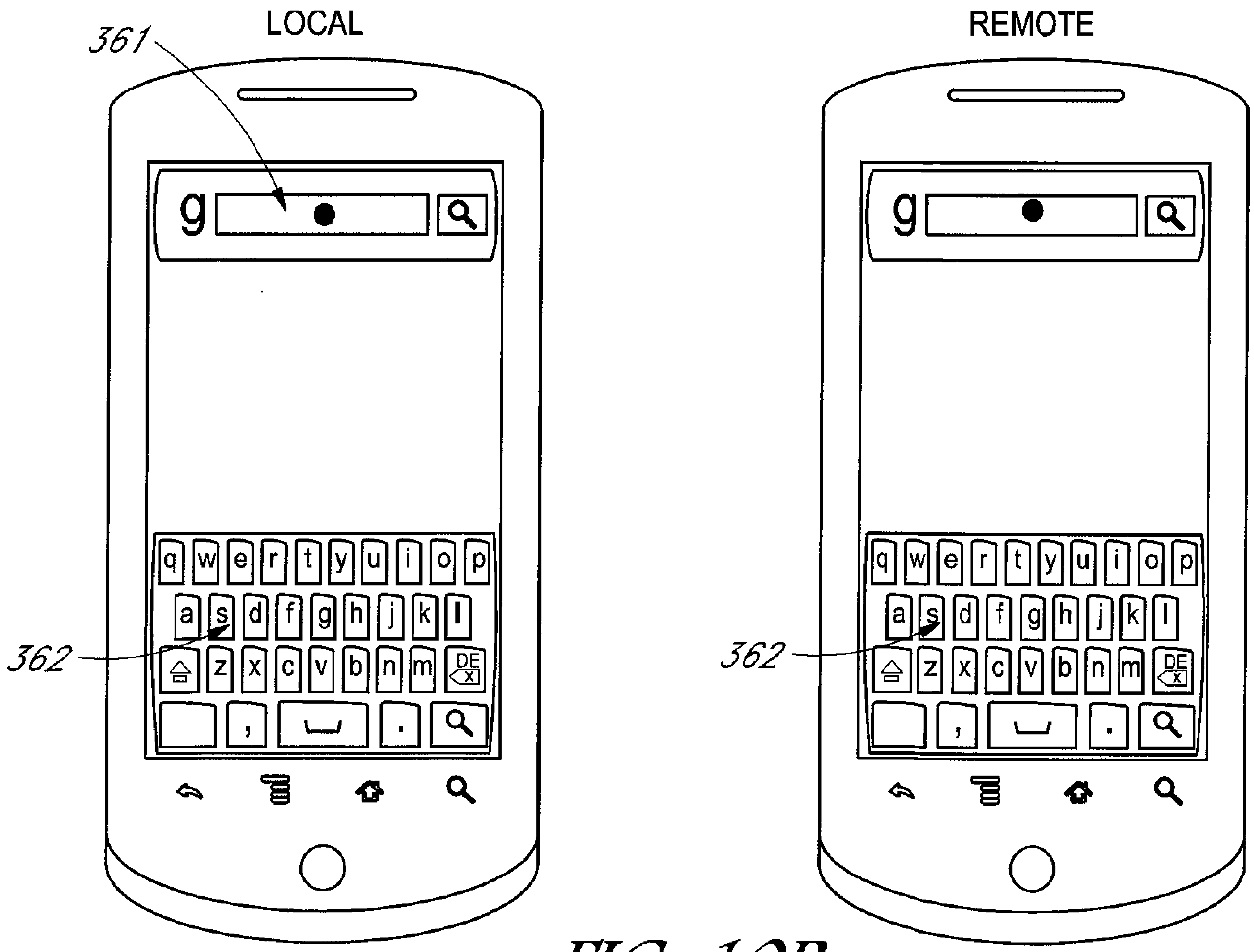

FIG. 10B

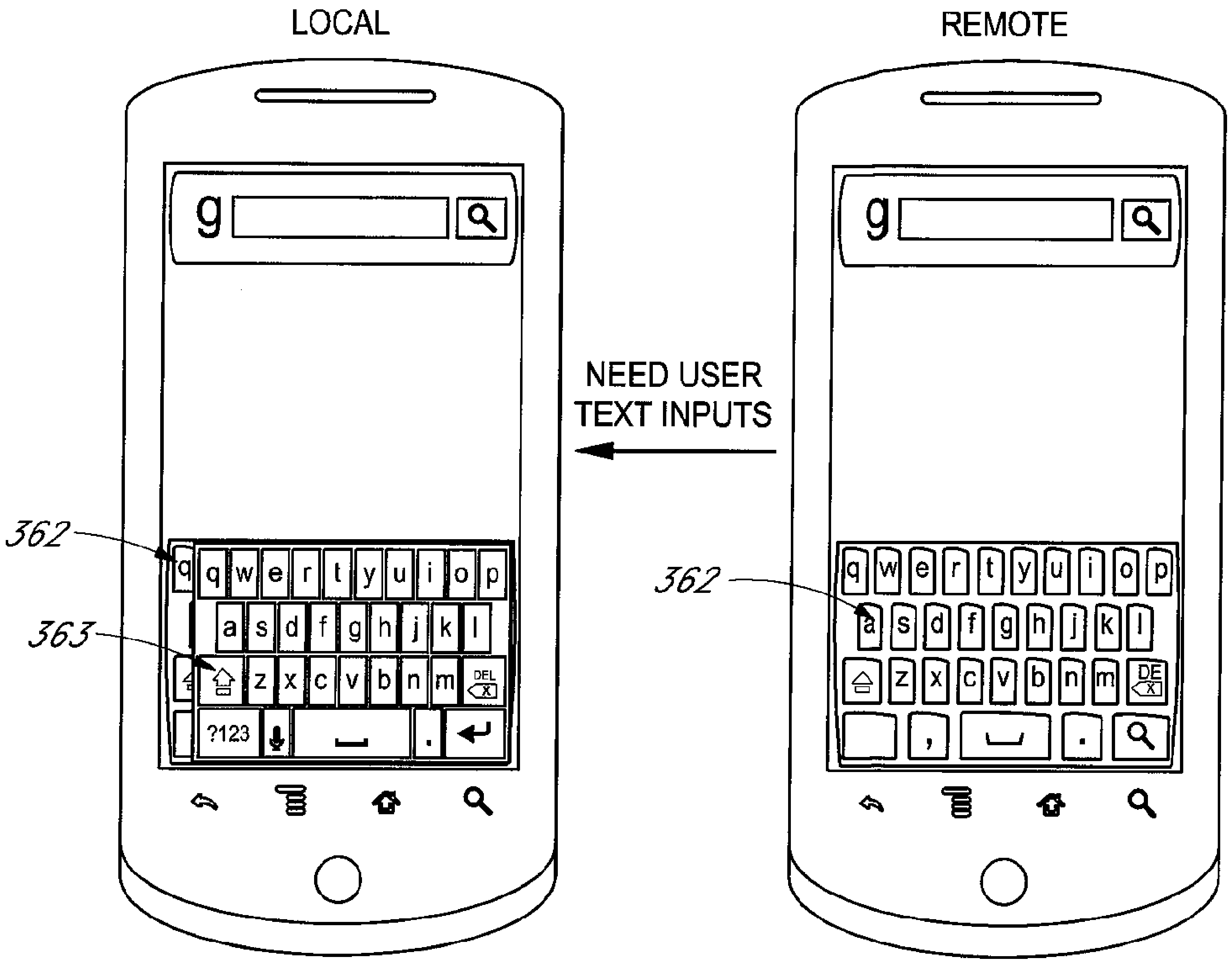

FIG. 10C

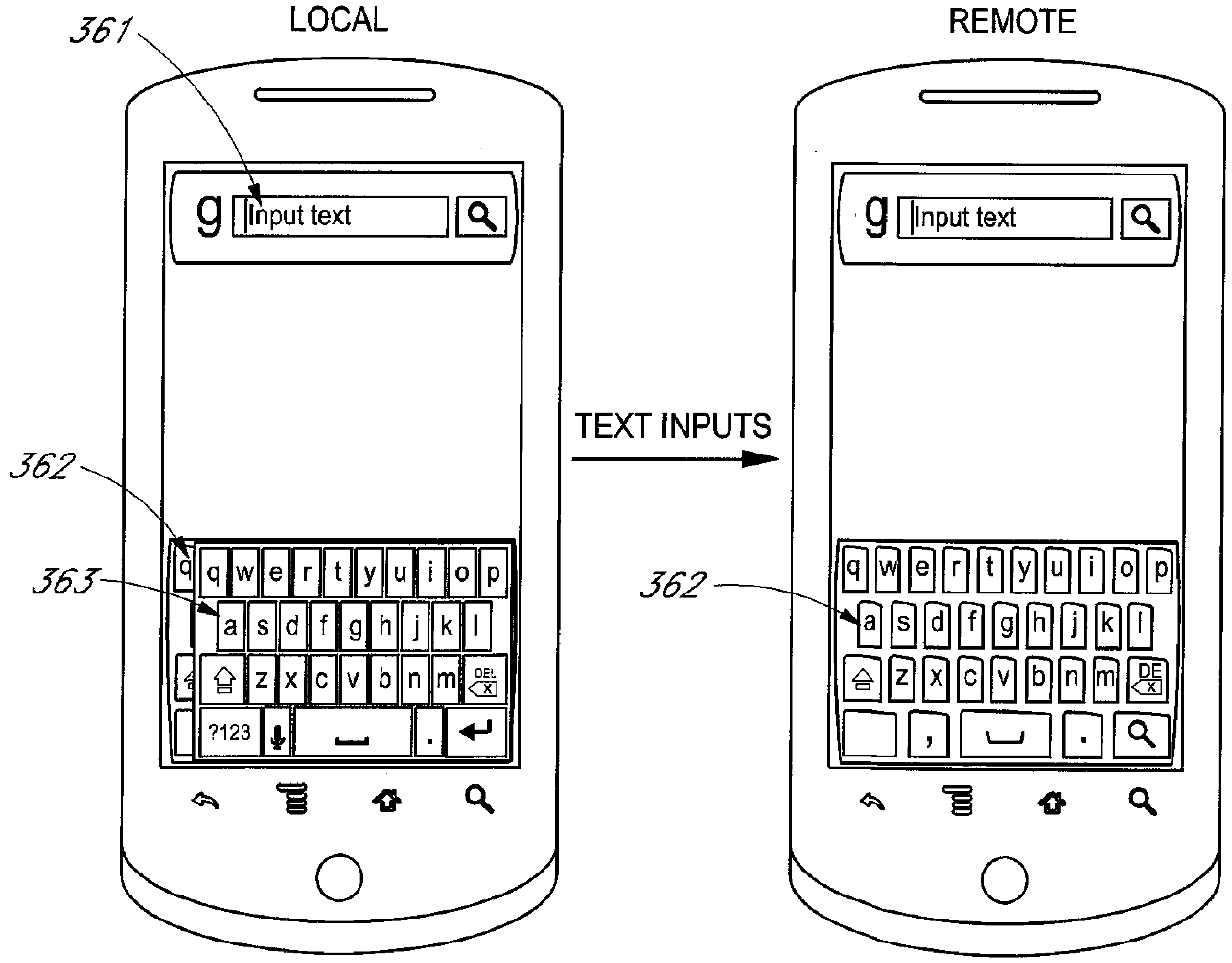

FIG. 10D

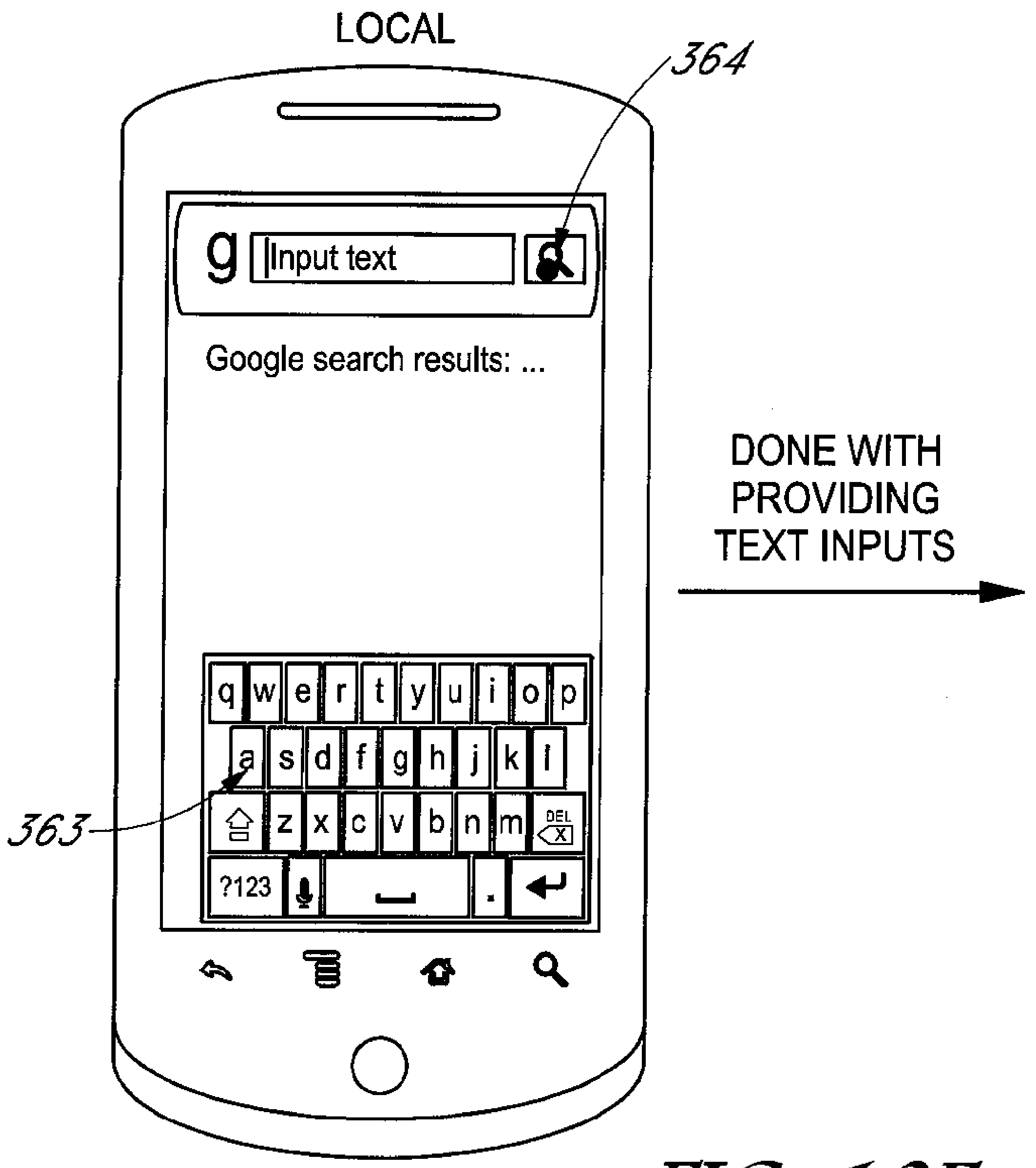

FIG. 10E

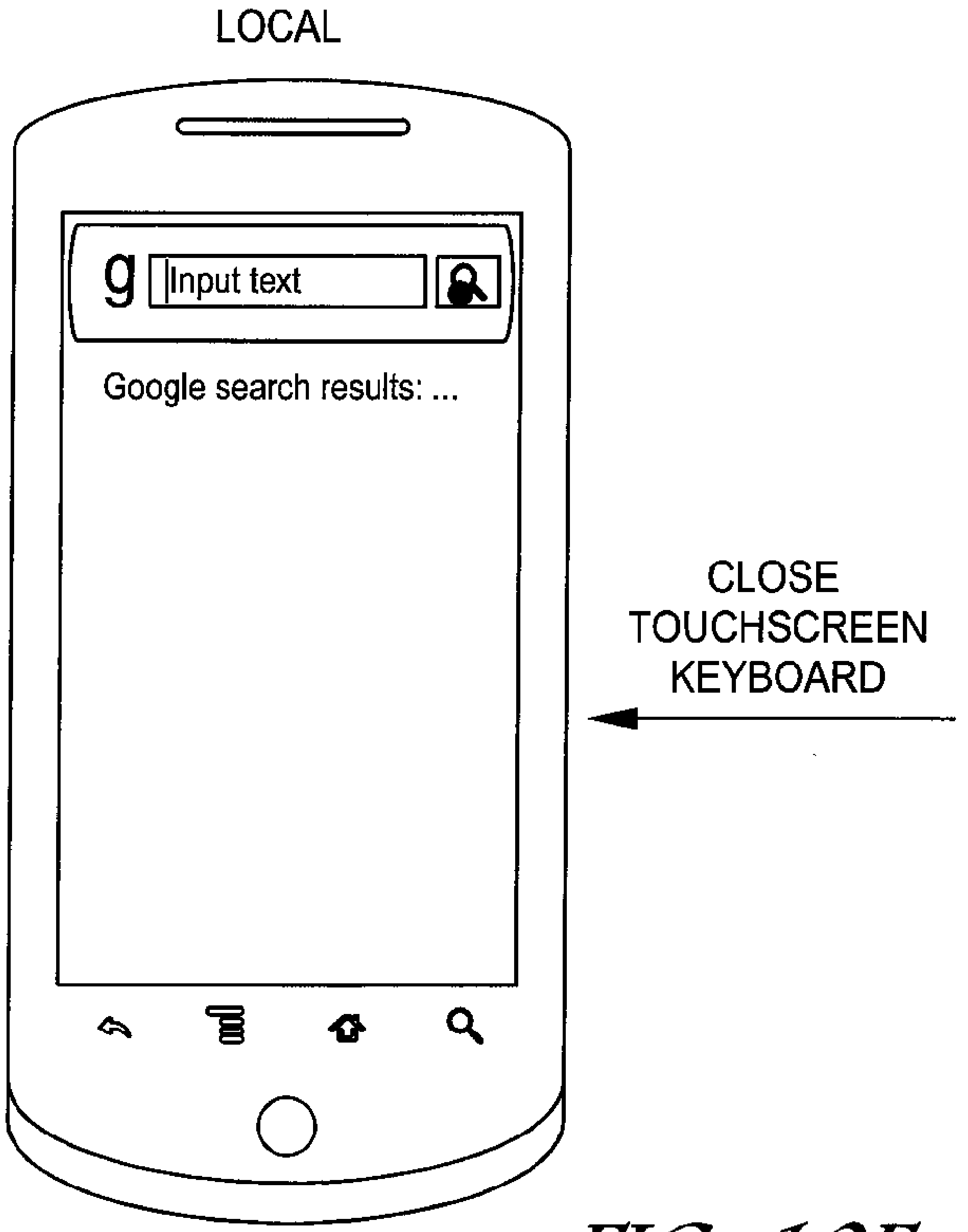

FIG. 10F

SYSTEMS AND METHODS FOR PROVIDING USER INPUTS TO REMOTE MOBILE OPERATING SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application No. 61/825,839, filed on May 21, 2013, which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to mobile devices, and more particularly but not exclusively to computing infrastructures for supporting operation of mobile devices.

2. Description of the Background Art

Mobile devices, such as smartphones and tablets, have become commonplace and are now employed as replacements for portable (e.g., laptops and netbooks) and desktop (e.g., personal computers) computing devices. For example, smartphones are now employed not just to make voice calls over traditional mobile telephone networks, but also to browse the Internet, watch streamed video, and play online games. Some employers even allow employees to bring their own devices, the so-called BYOD policy.

One problem with mobile devices is that they run mobile operating systems, such as the ANDROID and the iOS operating systems. Unlike traditional desktop operating systems, such as the WINDOWS operating system, mobile operating systems are not as powerful and extensible, allowing them to run securely on a mobile device that has limited computing resources. Accordingly, mobile devices running mobile operating systems cannot readily take advantage of some computing infrastructures available to computers that run desktop operating systems.

SUMMARY

In one embodiment, a virtual mobile infrastructure includes a mobile client device running a local mobile operating system and a server computer running a remote mobile operating system. The mobile client device displays a screen image of the remote mobile operating system. User text inputs for a remote application running on the remote mobile operating system are received by way of a touchscreen keyboard of a local input method editor (IME) of the local mobile operating system. The user text inputs are transmitted from the mobile client device to the server computer, where the text inputs are provided to the remote application by a virtual IME of the remote mobile operating system.

These and other features of the present invention will be readily apparent to persons of ordinary skill in the art upon reading the entirety of this disclosure, which includes the accompanying drawings and claims.

DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a schematic diagram of a computer that may be employed with embodiments of the present invention.

FIG. **2** shows a schematic diagram of a virtual mobile infrastructure in accordance with an embodiment of the present invention.

FIG. **3** shows a schematic diagram of a server computer running a plurality of ANDROID operating systems in accordance with an embodiment of the present invention.

FIG. **4** shows the three layers of an ANDROID operating system.

FIG. **5** shows a flow diagram of a method of multiplexing a plurality of ANDROID operating systems to a single kernel driver in accordance with an embodiment of the present invention.

FIG. **6** shows a schematic diagram illustrating components of a server computer and a mobile client device in accordance with an embodiment of the present invention.

FIG. **7** shows a flow diagram of a method of logging into one of a plurality of ANDROID operating systems in accordance with an embodiment of the present invention.

FIG. **8** shows a schematic diagram illustrating client-side rendering in accordance with an embodiment of the present invention.

FIG. **9** shows a schematic diagram of a virtual input method editor (IME) operating with a local IME in accordance with an embodiment of the present invention.

FIG. **10**, which consists of FIGS. **10A-10F**, shows screen shots illustrating an example operation of a virtual IME and a local IME in accordance with an embodiment of the present invention.

The use of the same reference label in different drawings indicates the same or like components.

DETAILED DESCRIPTION

In the present disclosure, numerous specific details are provided, such as examples of apparatus, components, and methods, to provide a thorough understanding of embodiments of the invention. Persons of ordinary skill in the art will recognize, however, that the invention can be practiced without one or more of the specific details. In other instances, well-known details are not shown or described to avoid obscuring aspects of the invention.

Referring now to FIG. **1**, there is shown a schematic diagram of a computer **100** that may be employed with embodiments of the present invention. The computer **100** may be employed as a mobile client device, a server computer for a virtual mobile infrastructure, and other devices described below. The computer **100** may have fewer or more components to meet the needs of a particular application. The computer **100** may include a processor **101**. The processor **101** may comprise an ARM processor when the computer **100** is a mobile client device or an x86 processor when the computer **100** is a server computer, for example. The computer **100** may have one or more buses **103** coupling its various components. The computer **100** may include one or more user input devices **102** (e.g., keyboard, touchscreen), one or more data storage devices **106** (e.g., flash memory, universal serial bus (USB) drive), a display monitor **104** (e.g., touchscreen, liquid crystal display), one or more communications interfaces **105** (e.g., network adapter, cellular interface), and a main memory **108** (e.g., random access memory). The computer **100** is a particular machine as programmed with software modules **110**. The software modules **110** comprise computer-readable program code stored non-transitory in the main memory **108** for execution by the processor **101**.

FIG. **2** shows a schematic diagram of a virtual mobile infrastructure (VMI) **200** in accordance with an embodiment of the present invention. In the example of FIG. **2**, the virtual mobile infrastructure **200** includes a VMI computer system **202**. The VMI computer system **202** may include a plurality of server computers **211**, with each server computer **211** running a plurality of mobile operating systems. As its name implies, a mobile operating system is an operating system designed to run on mobile devices, which are also referred to as "handheld devices." Examples of mobile devices include smartphones and tablets.

A mobile operating system is lightweight in that it consumes less computing resources, such as processor and memory resources, compared to desktop operating systems. A mobile operating system also supports communications over a mobile phone network, such as a cellular network, to provide telephony. In one embodiment, a server computer **211** comprises a single LINUX operating system server that runs several mobile operating systems in the form of ANDROID operating systems, with each ANDROID operating system being implemented on a LINUX container. A mobile operating system running on a server computer **211** is also referred to herein as a "remote mobile operating system" to distinguish it from a corresponding mobile operating system running on a mobile client device **201**. In general, components on a mobile client device **201** are referred to herein as "local" components, and components on the server computer **211** are referred to herein as "remote" components.

In the example of FIG. **2**, the virtual mobile infrastructure **200** includes one or more mobile client devices **201**, with each mobile client device **201** comprising a mobile device that runs a mobile operating system. The mobile operating system of a mobile client device **201** may be the same as a corresponding remote mobile operating system running on a server computer **211**. In one embodiment, the mobile client devices **201** each comprises a smartphone or tablet that runs the ANDROID operating system. An ANDROID operating system running on a mobile client device **201** is also referred to herein as a "local ANDROID operating system" and an ANDROID operating system running on a server computer **211** is also referred to herein as a "remote ANDROID operating system."

In other embodiments, a mobile operating system of a mobile client device **201** and a corresponding remote mobile operating system may be different mobile operating systems. For example, a mobile client device **201** may be running an iOS operating system and the remote mobile operating systems may be ANDROID operating systems.

A mobile client device **201** may communicate with the VMI computer system **202** to access one of a plurality of remote mobile operating systems running on a server computer **211** over a computer network, which may include the Internet and/or a private computer network. The remote mobile operating system, which comprises the ANDROID operating system in this example, includes a plurality of remote application programs (also commonly known as "applications" or "apps"). A user of the mobile client device **201** accesses the remote apps on the remote ANDROID operating system as if the remote apps are running on the mobile client device **201**. For example, the screen image of the remote ANDROID operating system is displayed on the touchscreen of the mobile client device **201**. The user may even replace the mobile client device **201** with another mobile client device **201** to access the same remote apps on the same remote ANDROID operating system. This is particularly advantageous in workplaces that allow employees to use their own personal mobile client devices. In particular, employees with different mobile client devices **201** can work on remote apps running on remote mobile operating systems that are owned and managed by their employers.

The ANDROID operating system is a so-called "touchscreen mobile operating system" in that it is primarily designed to work with touchscreen-enabled smartphones and tablets. These smartphones and tablets do not have physical keyboards. Instead, they have touchscreen keyboards (also known as "virtual keyboards") that are displayed on the touchscreen. Accordingly, the ANDROID operating system has provisions for an input method editor (IME) that allows a user to enter text by way of a touchscreen keyboard displayed by the IME. In one embodiment, a mobile client device **201** may provide text inputs to a corresponding remote ANDROID operating system using a local IME of the local ANDROID operating system. The text inputs are received by a local IME of a client application, which provides the text inputs to a virtual IME running on the remote ANDROID operating system. The virtual IME provides the user inputs to the corresponding remote application running on the remote ANDROID operating system.

In one embodiment, the VMI **200** employs client-side rendering to display a screen image of a remote ANDROID operating system on the mobile client device **201**. More specifically, the final screen image of the remote ANDROID operating system may be completed locally on the mobile client device **201**. For example, data for drawing surfaces and data for compositing the surfaces to create a final screen image may be generated on the remote ANDROID operating system and then sent to the mobile client device **201**. There, the final screen image is generated by locally drawing the surfaces and compositing the surfaces on the local ANDROID operating system.

Client-side rendering minimizes network bandwidth consumption by not having to transmit the final screen image over the computer network. However, graphics generation, in general, is computation intensive and increases battery consumption. In one embodiment, a mobile client device **201** performs client-side rendering during normal operation, but changes to server-side rendering when its battery level is below a certain battery threshold. With server-side rendering, the final screen image is generated on the remote ANDROID operating system and the pixel information of the final screen image is sent to the mobile client device **201**.

In the example of FIG. **2**, the plurality of server computers **211** of the VMI computer system **202** may share data storage devices by way of, for example, a distributed file system (DFS). The VMI computer system **202** may also take advantage of cloud services **204**, such as remote backups, and other computing infrastructures, such as administrator (AD) support, database (DB) access, and backup services, that are typically available in an enterprise network.

FIG. **3** shows a schematic diagram of a server computer **211** running a plurality of ANDROID operating systems in accordance with an embodiment of the present invention. In one embodiment, the components shown in FIG. **3** comprise computer-readable program code that may be stored in main memory and executed by a processor of the server computer **211**. In the example of FIG. **3**, the server computer **211** runs the LINUX operating system, which supports a plurality of remote ANDROID operating systems **224**. In one embodiment, each remote ANDROID operating system **224** is implemented in its own, separate LINUX container. That is, each server computer **211** runs a plurality of LINUX containers, with each container supporting an ANDROID operating system.

As is well known, an ANDROID operating system has three layers, namely, an ANDROID application layer, an ANDROID system layer, and a LINUX kernel. Referring to FIG. **4**, which shows the three layers of an ANDROID operating system, the ANDROID application layer is the topmost layer and includes the applications. Below the ANDROID application layer is the ANDROID system layer, which includes the application framework, the libraries, and the ANDROID runtime. The ANDROID runtime includes a Dalvik process virtual machine, which is a process virtual machine for running an application. In contrast to a system virtual machine, which supports execution of an entire operating system, a process virtual machine supports execution of a single program. The ANDROID system runs on top of a LINUX kernel, which provides device drivers and other kernel functions.

In marked contrast to hosted virtualization where each virtual machine has its own guest operating system that runs on and is separate from a host operating system, the ANDROID operating systems **224** of the server computer **211** share the same LINUX kernel. More particularly, each ANDROID operating system **224** has its own applications **225** and an ANDROID system **226** with a Dalvik process virtual machine. However, all of the remote ANDROID operating systems **224** share the same, single kernel **223**; a container does not have a kernel. In one embodiment, the kernel **223** includes a LINUX kernel and additional ANDROID kernel drivers for supporting an ANDROID operating system. The ANDROID kernel drivers are merged with the LINUX kernel to create the kernel **223**, which is then made the boot kernel of the LINUX operating system of the server computer **211**. The server computer **211** may comprise an x86 processor that runs the LINUX operating system, and thus includes a LINUX kernel in the form of the kernel **223**, and a LINUX supervisor and console **221**.

In one embodiment, the kernel **223** includes an ANDROID driver multiplexer **227**, which comprises computer-readable program code for allowing multiple ANDROID systems **226** to access the same kernel device driver. The ANDROID driver multiplexer **227** multiplexes several ANDROID systems **226** to a single kernel device driver as now explained with reference to FIG. **5**.

FIG. **5** shows a flow diagram of a method of multiplexing a plurality of ANDROID operating systems to a single kernel driver in accordance with an embodiment of the present invention. In one embodiment, the method of FIG. **5** is performed by the ANDROID driver multiplexer **227**. In the example of FIG. **5**, the ANDROID system **226-1** is of a first ANDROID operating system **224** on a container, and the ANDROID system **226-2** is of a second ANDROID operating system **224** on its own, separate container. The driver multiplexer **227** allows both ANDROID systems **226-1** and **226-2** to access the same kernel device driver **240** on the kernel **223**, one after another.

In the example of FIG. **5**, the driver multiplexer **227** creates a context for an ANDROID system **226** if one is not available. A context comprises a set of data saved for an ANDROID system **226**. When an ANDROID system **226** accesses a kernel device driver, the driver multiplexer **227** checks to see if this is the first time the ANDROID system **226** accesses the driver (step **232**). If so, the driver multiplexer **227** creates a context for accessing the driver for the ANDROID system (step **233**). When the ANDROID system **226** has previously accessed the driver, the driver multiplexer **227** simply retrieves the saved context for the ANDROID system **226** and switches to that context (step **234**) to access the driver.

In the example of FIG. **5**, the ANDROID system **226-1** makes a request to access the kernel device driver **240** (see arrow **231**). If this is the first time the ANDROID system **226-1** is accessing the kernel device driver **240**, the driver multiplexer **227** creates a context **241** for the ANDROID system **226-1**. The driver multiplexer **227** switches to the context **241** to allow the ANDROID system **226-1** to access the kernel device driver **240**. The driver multiplexer **227** saves all context data for the ANDROID system **226-1** to the context **241**. Thereafter, the ANDROID system **226-2** makes a request to access the kernel device driver **240** (see arrow **236**). In this example, the ANDROID system **226-2** already has a saved context **242**. Accordingly, the driver multiplexer **227** simply switches from the context **241** (or some other previous context) to the context **242** to allow the ANDROID system **226-2** to access the kernel device driver **240**.

FIG. **6** shows a schematic diagram illustrating the components of a server computer **211** and a client device **201** in accordance with an embodiment of the present invention. As shown in FIG. **6**, a server computer **211** may be running a plurality of remote ANDROID operating systems **224**. A remote ANDROID operating system **224** includes a plurality of applications **225** on an application layer and an ANDROID system **226** with its Dalvik process virtual machine for executing the applications **225**. A device emulation **252** allows the ANDROID system **226**, which is typically designed to operate on an ARM processor, to run on the x86 processor of the server computer **211**. In one embodiment, each remote ANDROID operating system **224** includes a remote access daemon **251** for communicating with and servicing service requests from a client application **262** running on the mobile client device **201**.

In the example of FIG. **6**, the client mobile device **201** may comprise a conventional smartphone running a local ANDROID operating system. The local ANDROID operating system has a plurality of applications **261** on an application layer, an ANDROID system **263**, and a LINUX kernel **264**. The ANDROID system **263** has a Dalvik process virtual machine for executing the applications **261** on the ARM processor of the client mobile device **201**.

In one embodiment, the client mobile device **201** includes the client application **262**. In one embodiment, the client application **262** comprises computer-readable program code for communicating and interfacing with a remote ANDROID operating system **224** running on the server computer **211** to allow a user of the client mobile device **201** to access a remote application **225** Like other applications, the client application **262** is running on application layer of the local ANDROID operating system.

Referring to FIG. **7**, the client application **262** may connect to one of the plurality of remote ANDROID operating systems **224** by way of a login server **280** running on the server computer **211**. During a registration process, the client application **262** logs into the login server **280** to provide a username and password for accessing a particular remote ANDROID operating system **224** (see arrow **281**). When the client application **262** has been authenticated as being authorized to access the remote ANDROID operating system **224**, the login server **280** provides the client application **262** the remote ANDROID's **224** connection address and a security token (see arrow **282**). Thereafter, the client application **262** may connect to the remote ANDROID operating system **224** by providing access information (e.g., the username and password) and the security token (see arrow **284**). The remote ANDROID operating system **22** allows access to the client application **262** after authenticating the client application **262** (see arrow **285**).

Continuing with FIG. **6**, on the server computer **211**, a remote access daemon **221** receives user inputs (see arrow **271**) and sensor information (see arrow **273**; e.g., accelerometer or gyroscope information of the client device **201**) from the client application **262** and provides the user inputs and sensor information to a corresponding component on the remote ANDROID operating system **224**. In the case of client-side rendering, the remote access daemon **221** may receive screen data for generating a final screen image and provide the screen data to the mobile client device **201**, where the screen data are processed to locally generate the final screen image for display on the touchscreen of the mobile client device **201**. As will be more apparent below, the screen data may comprise drawing API calls and compositing data intercepted on the remote ANDROID operating system **224** and redirected to the client application **262** on the local ANDROID operating system.

FIG. **8** shows a schematic diagram that illustrates client-side rendering in the virtual mobile infrastructure **200** in accordance with an embodiment of the present invention. In the example of FIG. **8**, a remote ANDROID operating system **224** includes a graphics engine **310** and a graphics compositing engine **311**. The graphics engine **310** and the graphics compositing engine **311** may comprise services or components provided by the ANDROID system **226** of the remote ANDROID operating system **224**. In one embodiment, the graphics engine **310** may comprise the ANDROID SKIA graphics engine for two-dimensional (2D) graphics and the ANDROID OpenGL ES graphics engine for three-dimensional (3D) graphics, and the graphics compositing engine **311** may comprise the ANDROID SurfaceFlinger graphics compositing engine.

Generally speaking, in an ANDROID operating system, the final screen image to be displayed on the touchscreen comprises a plurality of surfaces that are composited together. Each of the surfaces may comprise a screen image for an application. More particularly, each of the remote applications **225** may issue drawing commands, e.g., by making application programming interface (API) calls to the graphics engine **310** to generate a surface (see arrows **320**). For example, an application **225** may issue drawing API calls to generate a surface for a background and another application **225** may issue drawing API calls to generate a surface for icons. The graphics engine **310** receives the drawing API calls and generates the corresponding surfaces (see arrows **321**). The graphics compositing engine **311** receives the surfaces (see arrows **322**) and creates the final screen image by compositing the surfaces together (see arrow **323**). In the just-mentioned example, the graphics compositing engine **311** generates a final screen image showing a background and icons, i.e., the composited screen images of the applications **225**. The final screen image is stored in a frame buffer for subsequent displaying on the touchscreen. In the case of server-side rendering, a corresponding remote access daemon **251** sends the pixel information of the final screen image to the mobile client device **201**. That is, in server-side rendering, the completed final screen image is sent to the mobile client device **201**. Because of the relatively large size of the final screen image, server-side rendering consumes a large amount of network bandwidth.

In the case of client-side rendering, the final screen image generated by the remote ANDROID operating system is not forwarded to the mobile client device **201**. Instead, screen data for generating the final screen image are sent from the remote ANDROID operating system to the mobile client device **201**. There, the screen data are processed to locally generate the final screen image. More specifically, for client-side rendering, drawing API calls made by the remote applications **225** to generate surfaces and the compositing data for compositing the surfaces together are intercepted on the remote ANDROID operating system and redirected to the local ANDROID operating system.

In the example of FIG. **8**, client-side rendering is performed by intercepting drawing API calls made by the applications **225**. Compositing data for compositing the surfaces together to form the final screen image are also intercepted. The interception of drawing API calls and compositing data may be performed by a hook module running in each individual remote ANDROID operating system **224** at the ANDROID system **226** layer. The hook module may hook API calls to the ANDROID Skia graphics engine for 2D graphics and to the ANDROID OpenGL ES graphics engine for 2D or 3D graphics. The hook module may also hook compositing data for compositing multiple surfaces to generate the final screen image. The hook module may hook surface creation/deletion/locking/unlocking events and each of the surface's attributes, such as size, position, z-order, etc. More specifically, in one embodiment, the hook module may intercept the following:

Surface Creation. For example, hooking the ANDROID SurfaceFlinger to get a a new surface's ID, width, height, and bitmap format.

Surface Deletion. For example, hooking the ANDROID SurfaceFlinger to get a deleted surface's ID.

Surface Lock. For example, hooking surface JNI (Java Native Interface) interface to get the mapping between surface ID and backend buffer's address, such as <surface_id, front_buffer_address, back_buffer_address>.

Surface Unlock. For example, hooking surface JNI interface to the surface unlock event.

Surface Drawing. For example, hooking the ANDROID Skia's primitive API in SkCanvas to get the following relationship: <SK_API, buffer_address>.

Surface Attribute. For example, hooking SurfaceFlinger to get surface attribute change, such as size, position, z-order.

Other data for creating a final screen image may also be intercepted without detracting from the merits of the present invention.

In the example of FIG. **8**, a remote access daemon (see **251** in FIG. **6**) redirects the intercepted drawing API calls (see arrow **301**) and compositing data (see arrow **302**) to the mobile client device **201**. There, the client application **262** running on the local ANDROID operating system receives the drawing API calls, and makes the drawing API calls to the local graphics engine on the local ANDROID operating system to locally draw the corresponding surfaces **312**. A surface compositor **313** of the client application **262** receives the surfaces **312** (see arrow **303**) and generates the final screen image (see arrow **304**) that is displayed on the touchscreen of the mobile client device **201** by compositing the surfaces **312** together.

More specifically, the client application **262** may create the surfaces **312** with double-buffer (front and back) using the same ID and size as on the remote ANDROID operating system. The client application **262** may then lock the surfaces **312** to bind the front buffer to the context of the ANDROID Skia or OpenGL ES graphics engine, whichever is applicable. The client application **262** unflattens the stream of redirected drawing API calls and executes them, by making the drawing API calls to the applicable graphics engine, to draw the surfaces **312**. The client application **262** then unlocks the surfaces **312** to trigger the surface compositor **313** to generate the final screen image by compositing the surfaces **312**. The client application **262** thereafter updates the attributes of the surfaces **312** as needed.

In one embodiment, the virtual mobile infrastructure **200** employs a local input method editor (IME) to provide user inputs to a remote ANDROID operating system. This feature of the virtual mobile infrastructure **200** is schematically illustrated in FIG. **9**.

In the example of FIG. **9**, a user of a mobile client device **201** employs the client application **262** to access a remote application **225** running on a remote ANDROID operating system **224**. The application **225** employs a virtual IME **341** to receive user inputs (see arrow **342**). The virtual IME **341** may comprise an ANDROID application with IME services. The virtual IME **341** displays its touchscreen keyboard whenever the application **225** requires user inputs. Because the client application **262** is accessing the remote ANDROID operating system **224**, the touchscreen keyboard of the virtual IME **341** is also displayed on the mobile client device **201** (see arrow **343**) by client-side rendering, for example. When the user needs to enter text input, the client application **262** hides the touchscreen keyboard of the virtual IME **341** from the client mobile device **201** and invokes a local IME **340** that uses a local IME service, for example. This allows the user to enter text inputs via the touchscreen keyboard of the local IME **340**. The client application **262** receives the text inputs from the local IME **340**, and sends the text inputs to the virtual IME **341** (see arrow **344**), which then provides the text inputs to the remote application **225**.

FIG. **10**, which consists of FIGS. **10A-10F**, shows screen shots illustrating an example operation of the virtual IME **341** and the local IME **340** in accordance with an embodiment of the present invention. In the example of FIG. **10**, the left hand figures show screen shots of the local ANDROID operating system and the right hand figures show screen shots of the remote ANDROID operating system. As explained, the remote ANDROID operating system is one of a plurality of ANDROID operating systems running on a server computer **211** (see FIG. **2**). Accordingly, the remote ANDROID operating system is not running on a tablet and may not have a touchscreen or display screen as shown. FIG. **10** is provided for illustration purposes only.

In FIG. **10**A, the local ANDROID operating system (on the left) and the remote ANDROID operating system (on the right) are initially displaying the same screen image.

In FIG. **10**B, the user touches a text input region **361** on the screen of the local ANDROID operating system. The touch event is passed to the remote ANDROID operating system, which automatically invokes the virtual IME **341** to display a touchscreen keyboard **362**. Because the client application **262** is displaying the screen image of the remote ANDROID operating system, the touchscreen keyboard **362** of the virtual IME **341** is also displayed on the local ANDROID operating system. As can be appreciated, using the IME **341** for the remote ANDROID operating system and corresponding remote applications allows for context-sensitive automatic displaying of a touchscreen keyboard.

In FIG. **10**C, the virtual IME **341** informs the client application **262** that a remote application **225** (e.g., a web browser or searcher) is accepting user text inputs; optionally the virtual IME **341** also informs the client application **262** the preferred keyboard type of the user. In response to receiving the information, the client application **262** automatically invokes the local IME **340**, which displays a touchscreen keyboard **363**. The touchscreen keyboard **363** of the IME **340** is displayed over the touchscreen keyboard **362** of the remote ANDROID operating system. FIG. **10**C shows a portion of the touchscreen keyboard **362** being visible on the local ANDROID operating system for illustration purposes only. In practice, the touchscreen keyboard **363** of the IME **340** is displayed to cover up the touchscreen keyboard **362** of the virtual IME **341**. This way, the user will not notice that the remote ANDROID operating system is still displaying the touchscreen keyboard **362** of the virtual IME **341**, which is displayed underneath the touchscreen keyboard **363**.

In FIG. **10**D, the user enters text into the text input region **361** using the touchscreen keyboard **363** of the IME **340**. The client application **262** receives the text inputs from the IME **340**, and provides the text inputs to the virtual IME **341**. This results in the text inputs being provided to the remote application **225** and being shown on the touchscreen of the remote ANDROID operating system. The screen image of the remote ANDROID operating system is reflected on the local ANDROID operating system. This results in the text inputs appearing in the text input region **361** of the local and remote ANDROID operating systems.

In FIG. **10**E, the user performs an action that indicates end of user input. In the example of FIG. **10**E, this is performed by the user by touching a "go" or "search" button **364** on the touchscreen of the local ANDROID operating system. The client application **262** informs the remote ANDROID operating system of the user action. In response to the user action, the remote ANDROID operating system dismisses the virtual IME **341**, which in turn closes the touchscreen keyboard **362** on the remote ANDROID operating system. Accordingly, the touchscreen keyboard **362** is no longer displayed on the remote and local ANDROID operating systems.

Before closing, the virtual IME **341** so informs the client application **262**. In response, as shown in FIG. **10**F, the client application **262** dismisses the IME **340** to close the touchscreen keyboard **363**.

While specific embodiments of the present invention have been provided, it is to be understood that these embodiments are for illustration purposes and not limiting. Many additional embodiments will be apparent to persons of ordinary skill in the art reading this disclosure.

What is claimed is:

1. A system comprising:

a server computer comprising a processor, memory, and a storage device, the memory of the server computer comprising instructions that when executed by the processor of the server computer causes the server computer to run a remote mobile operating system that comprises an application layer with applications that run on top of a system layer with a Dalvik process virtual machine that executes a first application being accessed by a user of a mobile client device over a computer network, wherein the remote mobile operating system receives user text inputs from the mobile client device and provides the user text inputs to the first application, and generates a touchscreen keyboard of a remote input method editor (IME) of the remote mobile operating system; and

the mobile client device comprising a processor, memory and a storage device, the memory of the mobile client device comprising instructions that when executed by the processor of the mobile client device causes the mobile client device to run a local mobile operating system, and display a screen image of the remote mobile operating system, wherein the local mobile operating system automatically displays a touchscreen keyboard of a local IME of the local mobile operating system over the touchscreen keyboard of the remote IME in response to information from the server computer that the first application is accepting the user text inputs, wherein the remote touchscreen keyboard from the remote IME is hidden from a user of the mobile device, and wherein the local mobile operating system receives the user text inputs from the touchscreen of the local IME, and provides the user text inputs to the server computer by transmitting from the mobile client device over the computer network to the server computer.

2. The system of claim **1** wherein the mobile client device automatically closes the touchscreen keyboard of the local IME when the touchscreen keyboard of the remote IME is closed on the server computer.

3. The system of claim **1** wherein the mobile client device comprises a smartphone.

4. The system of claim **1** wherein the mobile client device comprises a tablet.

5. The system of claim **1** wherein the local mobile operating system has a system layer that has a Dalvik process virtual machine.

6. The system of claim **1** wherein the user text inputs are received in the server computer by the remote IME and the remote IME provides the text inputs to the first application.

7. A computer-implemented method comprising:

displaying in a mobile client device a screen image of a remote mobile operating system wherein the remote mobile operating system is one of a plurality of remote mobile operating systems running on a server computer;

accessing from the mobile client device a remote application running on the remote mobile operating system;

displaying in the mobile client device a remote touchscreen keyboard of a remote input media editor (IME) of the remote mobile operating system;

in response to the remote application accepting user text inputs, automatically displaying a local touchscreen keyboard from a local IME of a local mobile operating system running on the mobile client device to receive the user text inputs in the mobile client device, wherein the local touchscreen keyboard of the local mobile operating system is displayed over the remote touchscreen keyboard of the remote mobile operating system, wherein the remote touchscreen keyboard of the remote IME is hidden from a user of the mobile client device;

transmitting the user text inputs from the mobile client device to the server computer over a computer network;

receiving by the server computer the user text inputs from the mobile client device; and

providing, in the server computer, the user text inputs to the remote application running on the remote mobile operating system.

8. The computer-implemented method of claim **7** wherein the remote mobile operating system includes a system layer comprising a Dalvik process virtual machine that executes the remote application.

9. The computer-implemented method of claim **7** wherein the remote mobile operating system and the local mobile operating system each includes a system layer that has a Dalvik process virtual machine.

10. The computer-implemented method of claim **7** wherein the mobile client device is a smartphone.

11. The computer-implemented method of claim **7** wherein the mobile client device is a tablet.

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